NPS-AM-11-C8P02R01-022

EXCERPT FROM THE

PROCEEDINGS

OF THE

EIGHTH ANNUAL ACQUISITION RESEARCH SYMPOSIUM WEDNESDAY SESSIONS VOLUME I

Delivering Savings with Open Architecture and Product Lines

Brian Womble, USN, and William Schmidt, Mike Arendt, and Tim Fain, IBM

Published: 30 April 2011

Prepared for the Naval Postgraduate School, Monterey, California 93943

ACQUISITION RESEARCH PROGRAM
GRADUATE SCHOOL OF BUSINESS & PUBLIC POLICY
NAVAL POSTGRADUATE SCHOOL

Report Documentation Page

Form Approved
OMB No. 0704-0188

1. REPORT DATE	2. REPORT TYPE	3. DATES COVERED
APR 2011		**00-00-2011 to 00-00-2011**

4. TITLE AND SUBTITLE	5a. CONTRACT NUMBER
Delivering Savings with Open Architecture and Product Lines	5b. GRANT NUMBER
	5c. PROGRAM ELEMENT NUMBER
6. AUTHOR(S)	5d. PROJECT NUMBER
	5e. TASK NUMBER
	5f. WORK UNIT NUMBER
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) **Naval Sea Systems Command (NAVSEA),Program Executive Office for Integrated Warfare Systems,Washington,DC,20376**	8. PERFORMING ORGANIZATION REPORT NUMBER
9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)	10. SPONSOR/MONITOR'S ACRONYM(S)
	11. SPONSOR/MONITOR'S REPORT NUMBER(S)

12. DISTRIBUTION/AVAILABILITY STATEMENT
Approved for public release; distribution unlimited

13. SUPPLEMENTARY NOTES
Presented at the Naval Postgraduate School?s 8th Annual Acquisition Research Symposium, 10-12 May 2011, Seaside, CA.

14. ABSTRACT
The unpredictable nature of the 21st century national security environment in conjunction with severe downward budgetary pressures has placed a new emphasis on achieving mission success with fewer resources. As the Department of Defense has sought to transform itself to meet this new requirement, Open Architecture (OA) has been viewed as one innovative tool for reducing costs (through greater efficiencies, enhanced competition, lower life-cycle cost, etc.) while maintaining the ability to quickly respond to the ever-changing threat environment. Consistent with this approach, product lines, based on OA foundational principles, have recently emerged as a means to streamline systems, achieve greater levels of reuse, and reduce costs. As directed by the Assistant Secretary of the Navy (Research Development and Acquisition, ASN[RDA]), the Naval Enterprise is preparing to implement Open Architecture Pilot Projects to validate a range of implementation approaches and evaluate their technical and business advantages as a means to attack budget and output deficiencies. This research topic will provide recommendations on how best to start implementing the product line approach in programs across the Naval Enterprise, consistent with current OA policy.

15. SUBJECT TERMS

16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT	18. NUMBER OF PAGES	19a. NAME OF RESPONSIBLE PERSON
a. REPORT	b. ABSTRACT	c. THIS PAGE			
unclassified	**unclassified**	**unclassified**	**Same as Report (SAR)**	**47**	

The research presented at the symposium was supported by the Acquisition Chair of the Graduate School of Business & Public Policy at the Naval Postgraduate School.

To request Defense Acquisition Research or to become a research sponsor, please contact:

NPS Acquisition Research Program
Attn: James B. Greene, RADM, USN, (Ret.)
Acquisition Chair
Graduate School of Business and Public Policy
Naval Postgraduate School
555 Dyer Road, Room 332
Monterey, CA 93943-5103
Tel: (831) 656-2092
Fax: (831) 656-2253
E-mail: jbgreene@nps.edu

Copies of the Acquisition Sponsored Research Reports may be printed from our website www.acquisitionresearch.net

ACQUISITION RESEARCH PROGRAM
GRADUATE SCHOOL OF BUSINESS & PUBLIC POLICY
NAVAL POSTGRADUATE SCHOOL

Preface & Acknowledgements

During his internship with the Graduate School of Business & Public Policy in June 2010, U.S. Air Force Academy Cadet Chase Lane surveyed the activities of the Naval Postgraduate School's Acquisition Research Program in its first seven years. The sheer volume of research products—almost 600 published papers (e.g., technical reports, journal articles, theses)—indicates the extent to which the depth and breadth of acquisition research has increased during these years. Over 300 authors contributed to these works, which means that the pool of those who have had significant intellectual engagement with acquisition issues has increased substantially. The broad range of research topics includes acquisition reform, defense industry, fielding, contracting, interoperability, organizational behavior, risk management, cost estimating, and many others. Approaches range from conceptual and exploratory studies to develop propositions about various aspects of acquisition, to applied and statistical analyses to test specific hypotheses. Methodologies include case studies, modeling, surveys, and experiments. On the whole, such findings make us both grateful for the ARP's progress to date, and hopeful that this progress in research will lead to substantive improvements in the DoD's acquisition outcomes.

As pragmatists, we of course recognize that such change can only occur to the extent that the potential knowledge wrapped up in these products is put to use and tested to determine its value. We take seriously the pernicious effects of the so-called "theory–practice" gap, which would separate the acquisition scholar from the acquisition practitioner, and relegate the scholar's work to mere academic "shelfware." Some design features of our program that we believe help avoid these effects include the following: connecting researchers with practitioners on specific projects; requiring researchers to brief sponsors on project findings as a condition of funding award; "pushing" potentially high-impact research reports (e.g., via overnight shipping) to selected practitioners and policy-makers; and most notably, sponsoring this symposium, which we craft intentionally as an opportunity for fruitful, lasting connections between scholars and practitioners.

A former Defense Acquisition Executive, responding to a comment that academic research was not generally useful in acquisition practice, opined, "That's not their [the academics'] problem—it's ours [the practitioners']. They can only perform research; it's up to us to use it." While we certainly agree with this sentiment, we also recognize that any research, however theoretical, must point to some termination in action; academics have a responsibility to make their work intelligible to practitioners. Thus we continue to seek projects that both comport with solid standards of scholarship, and address relevant acquisition issues. These years of experience have shown us the difficulty in attempting to balance these two objectives, but we are convinced that the attempt is absolutely essential if any real improvement is to be realized.

We gratefully acknowledge the ongoing support and leadership of our sponsors, whose foresight and vision have assured the continuing success of the Acquisition Research Program:

- Office of the Under Secretary of Defense (Acquisition, Technology & Logistics)
- Program Executive Officer SHIPS
- Commander, Naval Sea Systems Command
- Army Contracting Command, U.S. Army Materiel Command
- Program Manager, Airborne, Maritime and Fixed Station Joint Tactical Radio System

- Program Executive Officer Integrated Warfare Systems
- Office of the Assistant Secretary of the Air Force (Acquisition)
- Office of the Assistant Secretary of the Army (Acquisition, Logistics, & Technology)
- Deputy Assistant Secretary of the Navy (Acquisition & Logistics Management)
- Director, Strategic Systems Programs Office
- Deputy Director, Acquisition Career Management, US Army
- Defense Business Systems Acquisition Executive, Business Transformation Agency
- Office of Procurement and Assistance Management Headquarters, Department of Energy

We also thank the Naval Postgraduate School Foundation and acknowledge its generous contributions in support of this Symposium.

James B. Greene, Jr.
Rear Admiral, U.S. Navy (Ret.)

Keith F. Snider, PhD
Associate Professor

Panel 2 – Advancing Open Architecture Acquisition

Wednesday, May 11, 2011	
11:15 a.m. – 12:45 p.m.	**Chair: Christopher Deegan,** Executive Director, Program Executive Office for Integrated Warfare Systems ***Delivering Savings with Open Architecture and Product Lines*** Brian Womble, USN, and William Schmidt, Mike Arendt, and Tim Fain, IBM ***An Architecture-Centric Approach for Acquiring Software-Reliant Systems*** Lawrence Jones and John Bergey, Software Engineering Institute ***Advances in the Acquisition of Secure Systems Based on Open Architectures*** Walt Scacchi and Thomas Alspaugh, Institute for Software Research

Christopher Deegan—Executive Director, Program Executive Officer, Integrated Warfare Systems (PEO IWS). Mr. Deegan directs the development, acquisition, and fleet support of 150 combat weapon system programs managed by 350 military and civilian personnel with annual appropriations of over $5 billion.

Mr. Deegan holds a Bachelor of Science degree in Industrial Engineering from Penn State University, University Park, Pennsylvania and a Master of Science degree in Engineering from The Catholic University of America, Washington, DC. He is a graduate of the Program Managers Course, Defense Systems Management College, Fort Belvoir, VA. He is a Certified Acquisition Professional and is Level III certified in three DA WIA career fields: Program Management; Research and Systems Engineering; and Business, Cost Estimating and Financial Management.

Mr. Deegan is the only Comptroller employee to be recognized by the Association of Scientists and Engineers as "NAVSEA Engineer of the Year" (1993). He received the Assistant Secretary of the Navy (Research, Development and Acquisition) and NAVSEA Acquisition Excellence Awards (1996), the David Packard Award for Governmental Excellence (1996), the Navy's Meritorious Civilian Service Award (1997), the Navy's Competition and Procurement Excellence Award (2003), and a Meritorious Unit Commendation Medal as a member of the SEA WOLF Program Office (2006). Mr. Deegan was awarded the Presidential Rank of Meritorious Executive in October 2007.

Brian Womble—Mr. Womble was born and educated in Texas. He spent 16 years in software development for several firms in the Dallas Telecom Corridor and moved to the DC area in 1998. Mr. Womble worked for Lockheed Martin Manassas on a range of submarine acoustic and combat system development and Open Architecture efforts before joining NAVSEA and the Program Executive Office for Integrated Warfare Systems in December 2009. His professional interests include on-board test instrumentation and requirements testing. Mr. Womble received his undergraduate degree from University of Texas at Arlington and his master's in Electrical Engineering & Telecommunications from Southern Methodist University. [brian.womble@navy.mil]

William Schmidt—Founder and CEO of a Veteran Owned Small Business. William Schmidt, CDR, USN (Ret.), is the Lead for Open Architecture and Information Engineering and Technology support of Navy Programs at ANGLE Incorporated. CDR Schmidt has more than 40 years of operational, systems engineering, design, management, and management support experience in the Navy and defense-related industry. He uses his intimate knowledge of the Navy, ship and system acquisition, ship design and construction, and the challenges of operating a small business in the defense acquisition environment to run day-to-day operations in Angle Incorporated and support the introduction of new concepts and approaches for his defense clients. CDR Schmidt specializes in bringing state-of-the-practice technology to his clients to solve persistent problems and improve force capability and availability.

Mike Arendt—As a Senior Consultant at IBM, Mr. Arendt is currently providing consulting support to the United States Navy and Office of the Secretary of Defense. Mr. Arendt's Navy consulting role includes technical and business research and analysis for implementation of Naval Open Architecture principals throughout the Naval Enterprise. These efforts have recently been expanded to support the Under Secretary of Defense for Acquisition, Technology and Logistics (USD[AT&L]) in furtherance of his Better Buying Power initiative. Mr. Arendt is also serving an additional consulting support role to the Office of the Secretary of Defense (OSD), providing open business model subject matter expertise for OSD's Unmanned Air Systems (UAS) Integration-Integrated Product Team (I-IPT). Prior to working for IBM, Mr. Arendt served as a faculty research assistant at the University of Maryland's Center for Public Policy and Private Enterprise (CPPPE). At CPPPE, Mr. Arendt contributed to numerous research studies on topics including open architecture, oversight in shipbuilding, the defense industrial base, competition in defense acquisition, bid protests, defense acquisition workforce modernization, spiral development, COTS, and logistics modernization. Mr. Arendt is a current PhD candidate at the University of Maryland, School of Public Policy with a research concentration of Management, Finance and Leadership. Mr. Arendt's dissertation research is focused on Department of Defense supply-chain modernization. More specifically, his research seeks to identify strategies for the application and implementation of performance evaluation tools to benchmark DoD supply-chain transformation efforts. Mr. Arendt holds an MS in Defense and Strategic Studies from Missouri State University, a BA in Economics from The Ohio State University, and a BA in Political Science and Sociology from The Ohio State University. [mjarendt@us.ibm.com]

Tim Fain—As an Associate Partner at IBM with more than 30 years of technical, managerial, and consulting experience, Mr. Fain is the Lead for the Business Strategy Service Area in the Public Sector Strategy and Change Consulting Practice. He uses his extensive knowledge of federal regulatory and budgetary processes, e-Government principles and methodologies, and strategic planning to help public-sector clients address policy, service, and transformational challenges. Mr. Fain serves as a Public Sector Liaison to the IBM U.S. Defense Account Team, working closely with IBM account representatives to meet the needs of the Army, Navy, Air Force and other Defense clients. He is also the Public Sector Lead for IBM's "Smarter Strategies" offerings, helping federal installations and state and local governments develop strategies for using sensors, software systems, server infrastructure, network infrastructure, and optimized processes to deliver critical, cost-effective services. Prior to joining IBM, Mr. Fain spent eight years in the Executive Office of the President's Office of Management and Budget. Mr. Fain was commissioned through the NROTC program and served onboard the USS *Parche* (SSN 688). [tfain@us.ibm.com]

Abstract

The unpredictable nature of the 21st century national security environment in conjunction with severe downward budgetary pressures has placed a new emphasis on achieving mission success with fewer resources. As the Department of Defense has sought to transform itself to meet this new requirement, Open Architecture (OA) has been viewed as one innovative tool for reducing costs (through greater efficiencies, enhanced competition, lower life-cycle cost, etc.) while maintaining the ability to quickly respond to the ever-changing threat environment. Consistent with this approach, product lines, based on OA foundational principles, have recently emerged as a means to streamline systems, achieve greater levels of reuse, and reduce costs. As directed by the Assistant Secretary of the Navy (Research, Development and Acquisition, ASN[RDA]), the Naval Enterprise is preparing to implement Open Architecture Pilot Projects to validate a range of implementation approaches and evaluate their technical and business advantages as a means to attack budget and output deficiencies. This research topic will provide recommendations on how best to start implementing the product line approach in programs across the Naval Enterprise, consistent with current OA policy.

Introduction

The Naval Enterprise Acquisition Corps is being pressured to improve performance. National Security Systems—the weapon systems used to fight our wars—have realized cost growths outpacing rates of inflation. System deliveries are persistently late, driving costs even higher. In 2009, the Government Accountability Office reported that "the cumulative cost growth in the Department of Defense's portfolio (including the Naval Enterprise) of 96 Major Defense Acquisition Programs (MDAPs) was $296 billion from first estimates, and the average delay in delivering promised capabilities to the warfighter was 22 months" (GAO, 2009). Today's economic conditions place increased pressure on acquisition budgets. Likewise, political and civil unrest around the world has put a growing strain on the Navy's resources—including ships, aircraft, personnel and financial. Because of these influences, the Department's acquisition force has been asked to find ways to enhance mission performance, significantly lower costs, and increase quantity while maintaining the same or less budget.

Drawing upon experience in driving transformation through Open Architecture, the Navy is looking to take the next step towards improving how it acquires and supports its National Security Systems through Open Architecture Product Lines.

Background

Figure 1

A strong culture of achievement runs deep in the U.S. Naval Enterprise. It is a proud organization that plans carefully and executes smartly to continue its long winning tradition. Inherently, "we" collectively resist change as a conservative and understandable approach towards avoiding risk. What is our path when we are "shewn" an environment of avoidable hardship?

> Prudence, indeed, will dictate that Governments long established should not be changed for light and transient causes; and accordingly all experience hath shewn that mankind are more disposed to suffer, while evils are sufferable than to right themselves by abolishing the forms to which they are accustomed. But when a long train of abuses and usurpations, pursuing invariably the same Object evinces a design to reduce them under absolute Despotism, it is their right, it is their duty, to throw off such Government, and to provide new Guards for their future security. (Declaration of Independence)

We are not proposing to throw off the Government, but to throw off the behaviors that have led us to high costs and low output, collectively known as "poor performance in Acquisition."

The evolving and unpredictable threat environment coupled with enormous pressures on our nation's defense budget has caused the Naval Enterprise to consider dramatic changes in its approach to systems acquisition and sustainment. Our enemies are adaptive, continuously study our behavior, and counter with new behaviors of their own. They use Improvised Explosive Devices (IEDs) and suicide bombers to attack us at times and places of their choosing. Terrorists launch crude homemade rockets from within urban neighborhoods to invite collateral damage and attempt to wither our resolve. Constant change is attacking us, and these new threats, techniques, and situations demand that we change our planning models and build new systems to not only protect our soldiers, but to provide an adaptive advantage and protection from evolving threats. The Naval Enterprise must provide the warfighter with more than new systems. We must deliver evolving warfighting systems that are finely tuned, yet adaptable in days, not years. They must be designed for quick change, and to grow and change with little cost. We must leverage what we already have, and distribute solutions quickly to different systems and platforms.

The Naval Enterprise has been directed by ASN/RDA to execute a series of product line pilot projects in concert with current Naval Open Architecture efforts as a means to attack budget and output deficiencies. The following pages provide an overview of our approach.

Open Architecture

Open Architecture[1] (OA) can reduce costs and cycle time and speed insertion of new capabilities. OA is a development and program management technique providing a framework for creating systems that are less expensive to build and maintain, and deliver new features more quickly to the warfighter. The benefits of OA include reduced costs, shorter development schedules, and modularity. As defined by Guertin and Clements (2010), the following are core principles of the Open Architecture approach:

1. Modular designs with loose coupling and high cohesion that allow for independent acquisition of system components;
2. Continuous design disclosure, appropriate use of data rights allowing greater visibility into an unfolding design, and flexibility in acquisition alternatives;
3. Enterprise investment strategies that maximize reuse of system designs and reduce total ownership costs (TOC);
4. Enhanced transparency of system design through open peer reviews;
5. Competition and collaboration through development of alternative solutions and sources;
6. Analysis to determine which components will provide the best return on investment (ROI) to open, i.e., which components will change most often due to technology upgrades or parts obsolescence and have the highest associated cost over the lifecycle.

A design following these six principles as outlined by Guertin and Clements (2010) should result in an affirmative answer to the fundamental OA question: *Can a qualified third party add, modify, replace, remove, or provide support for a component of a system, based only on openly published and available technical and functional specifications of the component of that system?*

Product Lines

Creating and using product lines is a method to streamline the development of systems, generate opportunities for reuse, and reduce costs in development, testing, and logistics. A "Product Line," as we use the term, is a coordinated component design, sharing common, managed core building blocks which have attributes and features that satisfy the specific needs of a particular market segment or mission (Software Engineering Institute [SEI], n.d.). Product Line development results in a set of core modules and assets that form the cornerstones for building future National Security Systems. Assets include designs, patterns, drawings, source code, specifications and other cumulative products that are produced as part of an engineering effort to create a materiel solution. Product Lines can be viewed as a logical extension of several OA principles—in essence "Open Architecture in action."

As related to information technology, Product Lines exist for hardware, software, and a combination of both. Product Lines also apply to non-information technology specific solutions—such as automotive and mechanical systems. When properly implemented, Product Lines can decrease system lifecycle costs, lower risk, and shorten development time. Because the Product Line approach is centered upon reuse of existing assets,

[1] Definitions available at the Defense Acquisition University website (n.d.).

significant testing and validation is reduced, saving time and resources with follow-on benefits like improvements in component reliability.

Figure 2

Product Line Benefits

Lower Lifecycle Costs

More reuse produces more savings. Product Lines reuse core assets to create new products and systems, avoiding standalone development costs. Programs that use Product Line products realize cost avoidance savings. As designs, components, and products are reused across multiple programs, higher quantity orders improve production efficiencies, driving unit costs down. When a program adopts a Software Product Line, labor requirements as compared to new development are mostly limited to integration— lowering costs. Fielded Product Lines experience lower maintenance costs because of "seasoned" reliability, due to the maturity of the design and code. Examples of lower lifecycle costs from the Army's Common Avionics Architecture System (CAAS) Product Line include a 66.67% reduction in new system development costs, 50% reduction in integration costs, 50% reduction in software maintenance costs, and 95% reduction in training costs (Clements & Bergey, 2005).

Shorter Development Schedules

Developing hardware or software from scratch takes more time than beginning with a design that is near complete for the problem at hand. As noted by the Defense Science Board, a typical major system acquisition takes roughly 10–15 years. Development of comparable systems in the commercial sector is usually completed in anywhere from one third to one half the time. Acquisition of most information technology (e.g., national security systems and business systems) within the DoD exceeds typical commercial development timelines by anywhere between three to four times (DoD, 2009).

Product Quality

Designs that have already been through development, test, certification, and fielding are likely to perform better than those that have not. Beginning a project with a series of Product Lines which are already proven is a large advantage for the Naval Enterprise. The amount of development work needed is smaller, and smaller projects have higher rates of success. The cost for much of the testing can likely be "approved by extension" when the testing organization agrees that much of the implemented design has not changed.

Open Architecture and Product Lines Together

Open Architecture systems are decomposed into "subsystem" components, which become natural functionally partitioned units and a logical location to formulate a Product Line. In a similar fashion, Product Lines use core assets that are assembled and integrated in specific ways to create a family of products. When systems adopt the OA technical principles as articulated by Open Architecture Enterprise Team, they are in a position to take full advantage of Product Lines. The difficult parts of Product Lines, and for that matter, Open Architecture, are the business and marketplace rules that surround the Program. These rules are typically conceived or structured by the government. The following list of business constructs is typical of needed behavior for structuring and executing effective Product Lines. When implemented together, these constructs result in the creation of a "Product Line Factory."

1. **Data rights for technical data and computer software.** A minimum of Government Purpose Rights (GPR; DoD OA Working Group, 2011) is needed for Product Line success. Without requisite data rights for assets, there are limits on reuse and who the technical data and software source code can be shared with.
2. **Shared risks with other programs.** Product Lines are hinged upon providing products for use across multiple programs. Sharing risk among programs reduces costs to individual programs, and ultimately creates value-add for programs using the Product Line.
3. **Shared, common requirements across programs.** Product Line products must provide functionality that meets customer requirements. Within the DoD, requirements are typically written from a platform or system perspective. A Product Line approach requires merging requirements around capabilities to support establishing the assets needed to support the full scope of products within the Product Line. Managing "variation points" within a Product Line can mean the success or failure of software sharing opportunity, and the associated potential for saving time, money, and for delivering already tested, proven system components to the warfighter.
4. **Funding constructs that allow Product Line organizations to use funds from or across multiple programs.** Within a Product Line factory, shared core assets are used to create products in a prescribed way for use by many customers. The customers may use the products on different systems or platforms. The core asset base must be maintained to support the full family of products; it is not segregated into elements that support only one product. As soon as the Product Line has customers across program lines, funds will be mixed in supporting the asset base. Mechanisms for supporting mixed funding will be developed as necessary.

5. **Lines of authority that properly account for Product Line managers supporting many customers across programs, domains, and eventually, Services.** The scope of products in a Product Line can attract customers across program, domain, and Service boundaries. The Product Line model treats all users as customers with the same rights, responsibilities, and authority, regardless of organization. The DoD is not typically this organizationally agnostic. A Product Line manager will need a new model to function efficiently. While many industry approaches to producer/customer relationships do not fare well inside the government, it will be essential to find a workable structure to allow the Product Line and its customers to work effectively and productively as producer/consumer.

Naval Enterprise Product Line Pilot Projects

The Naval Enterprise is developing a series of frameworks for implementation and operation of a Product Line factory to provide an initial set of process, organization, procedure, and governance templates with development guides to support Product Line execution. These frameworks will be tested through a series of Product Line pilot projects. The pilot projects will begin with an existing product, while a framework is designed to support it. The strategy for conducting these pilots will begin with a "seed" product, followed by the construction of processes, an organization, and core asset base from that seed. Once these steps have been completed, a second candidate product for the Product Line will be selected to demonstrate the factory's ability to function successfully on a repeatable basis.

The Product Line project framework is a set of templates, draft procedures, example documents, and guides designed to be used as the starting points for the Product line pilot projects. The framework elements form a skeleton upon which the product line manager can build the essential business and technical structures necessary to get the project started. As projects use the framework and move through startup to operation, problems will be encountered requiring corrections, additions, and expansions. Carnegie Mellon University, Software Engineering Institute (CMU SEI) has published "A Framework for Product Line Practice, Version 5.0" (Northrop & Clements, et al., 2007) that provides extensive information on the technical and business practices integral to a software product line. The document also describes how these differ from standalone product practices. The Naval Enterprise framework differs from SEI's targeted commercial audience in that it is focused on startup structures inside the DoD (Northrop & Clements, et al., 2007). SEI is only one of several different product line frameworks; others have been developed, including an approach laid out by Kang, Sugumaran, and Park (2009).

Example templates and associated development guides include a new OA business case guide, the *Navy OA Contract Guidebook for Project Managers*, the CMU SEI Structured Intuitive Model for Product Line Economics (SIMPLE; Northrop & Clements, et al., 2007) economic model, and a guide on use within the Navy Enterprise, and a template for use in deciding which programs to select as Open Architecture Product line pilots.

The Product Line approach may require significant adjustments in the way the Navy typically does business. The Product Line factory will generate products that are used across programs and their associated funding lines. The products will fulfill requirements across different warfare areas and platforms. The Product Line factory manager will have responsibility to support and respond to multiple programs which may cross domain and Service lines. The pilot projects offer the opportunity to investigate these issues and craft effective solutions while creating functional organizations and delivering real products.

Framework templates are broken down into four phases to match a four phased approach to pilot project completion: deciding what to build (Phase I); developing the initial asset base (Phase II); developing the Product Line production and support machinery (Phase III); and operating the factory to create and support products, and implementing product variations (Phase IV). The templates are intended to address every task within each phase with special emphasis on tasks that are unique to Product Lines or that present special challenges in a Naval Enterprise environment. Addressing a Product Line scope, cross product funding, cross domain product support, and development and configuration management of a Product Line asset base and associated products represents the kind of tasks that are different from a non-product line acquisition approach.

The framework templates and supporting material will be revised during the pilots to reflect lessons learned and represent a key product of the pilot projects. Follow-on Product Line efforts will have a well-defined starting point for processes, governance, and organizational constructs that have been tested for effectiveness.

Steps to Product Lines

Our initial approach to Product Lines draws heavily on information from the CMU SEI (Northrop, 2004); the following outline provides a roadmap of activities that can be used to start up a new product line entity, as shown in Figure 3. These steps can be implemented in different order based on the relative organizational readiness for Product Line implementation. Several parallel activities can be worked simultaneously. Because this outline is a whole-lifecycle model, one should assume these activities occur over years rather than months.

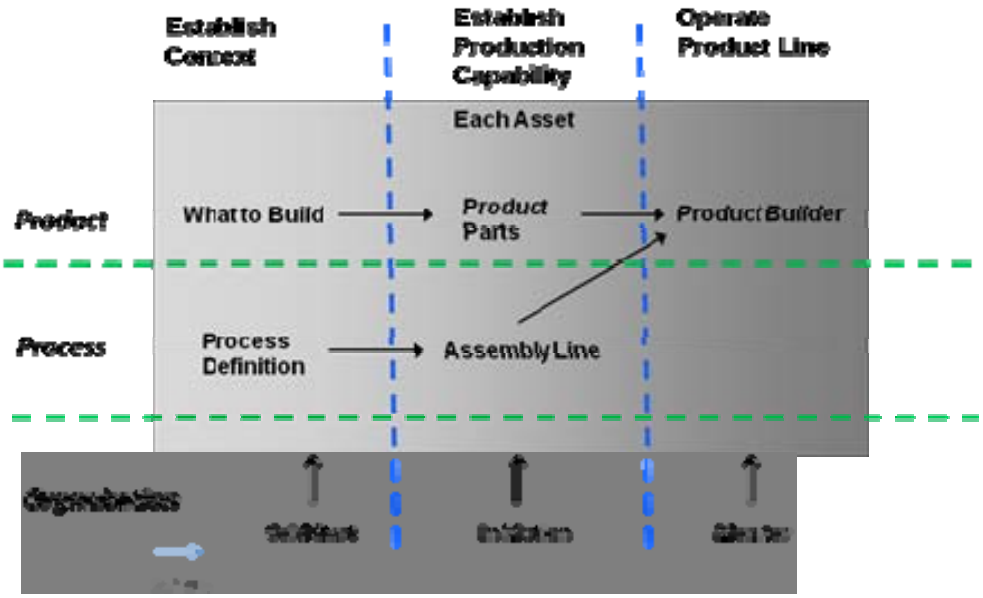


Figure 3. The Adoption Factory Pattern

(Northrop, 2004)

Phase I: What to Build

The decision to implement a Product Line starts with deciding where a program is with respect to the lifecycle of products being considered and assessing where those

products are going. Initiating a Product Line can take either of two approaches, proactive or reactive (Northrop, 2004). If starting with a clean sheet, the proactive approach is used to create the organization, the core asset base, the procedures and tools, and all the governance elements for the Product Line. If starting with an existing product, then the reactive approach can be used. In this approach, core asset components are dissected from the existing product while organization, processes and procedures, tools, and governance are either created from scratch or crafted by reorganizing and restructuring existing materials. In both cases, the first task is to define the Product Line scope and determine that it is a suitable approach from a business and technical perspective.

1. **Define and validate product line scope.** The first step in defining a Product Line is to develop a general scope statement. The scope is the definition of what attributes, behaviors, and aspects are within scope and those that are outside. This initial scope statement informs the business case and other analysis that follows, and in turn, is refined as those products are developed. The scope documentation will not be complete until the Product Line is complete. During implementation, the scope document continues to capture the commonalities that members of a Product Line share and the ways in which they differ.
    a. **Develop a business case.** Once you have decided to investigate the Product Line approach for a specific product area, a Business Case is needed to determine the efficacy of the approach (Northrop & Clements, et al., 2007, Building a Business Case section). The Business Case informs your deliberations by looking at projected costs, return on investment, risks, potential marketplace, and comparing and contrasting the advantages and disadvantages of a Product Line versus standalone product development approaches. The business case works hand in hand with the economic model to provide a qualitative and quantitative assessment of the costs and benefits of switching to a Product Line approach.
    b. **Develop a market description.** The market description tries to define the number of products that can be provided to customers across the proposed Product Line in breadth and depth (Northrop & Clements, et al., 2007, Market Analysis section). Looking across the Naval Enterprise, there are three classes of potential customers: those who are able and willing to use the products; those who are able but hesitant; and those who are unable (barred by contract or law). If there are insufficient potential customers in the able categories to generate significant cost savings through reuse, then the business case and economic model need to assess other advantages. Implementing a Product Line may still be justified by improvements in quality and rapid responsiveness to changing requirements.

Figure 4

c. **Conduct a technology assessment.** The technology assessment is focused on both ensuring that the technology necessary for implementing a Product Line for the products envisioned are available, and that the best set of technologies for implementing and operating the Product Line is selected (Northrop & Clements, et al., 2007, Technology Forecasting section). Within the confines of serial processing, Moore's Law can be used as a reasonable basis to describe the rate of change in available processing power which, in turn, enables advances in software technology that supports software automation, variation modeling, and new heuristics. In the future, it is probable that the pace of technological innovation from parallel processing and other advances will significantly alter the assumptions traditionally held under Moore's law. As a consequence, technology assessments may need to be updated to reflect such transformational changes in technology development (Dally, 2010). Process innovations and new strategies and techniques offer improvements in production and deployment of new products, configuration management, and customer support capabilities. Standards bodies continually process changes and additions to their products which often offer opportunities to increase commonality and reuse. All of these technology elements need to be factored into the selection of the initial product and the design of the Product Line. Once the Product Line factory is established, the technology assessment will become the starting point for the technology roadmap.

d. **Develop an economic model.** An economic model helps structure the assessment of the costs and benefits of adopting a Product Line approach in comparison with a standalone product approach. The Structured Intuitive Model for Product Line Economics (SIMPLE) described by Clements, McGregor, and Cohen (2005), is a general purpose business model that supports estimating the costs and benefits of adopting a product line. There are four basic cost functions provided in SIMPLE: (1) How much it costs to adopt the Product Line approach; (2) How much it costs to develop a core asset base for a particular scope; (3) How much it costs to develop the unique parts of a product that are not based on assets in the core asset base; and (4) How much it costs to build a product reusing the

core assets. The model can support a variety of scenarios by manipulating the four basic cost functions and developing benefit functions suitable to the particular application. The critical element in the economic model is providing the relevant parameters and data for the functions to accurately represent the costs and benefits. The SIMPLE Model is designed to be easily usable as a structured and intuitive tool and should be considered a starting point. Other economic modeling approaches are available for Product Line analysis. Model selection should be based on the resources available and the level of detail considered essential by the organization.

e. **Establish funding resource level for project.** Funding is essential to establish the Product Line. Completion of the business case analysis and economic model should provide solid footing for establishing the funding levels and profiles required. Identifying sources of funding in the DoD environment offers a unique challenge. A commercial entity would allocate funding based on projected sales, Product Line breadth and depth, and perceived market advantage. In this case, the private sector enterprise is trying to corner market share, and the investment is limited by the expected outcome. In the DoD, market share is meaningless, but increased buying power is extremely relevant to managers and enterprise executives. By determining the cost to start the Product Line versus the cost savings projected across the Product Line, a solid case for start-up budget can be established.

2. **Map project to initial pilot project execution plan.** With resources, the business case, and technology assessment in hand, and the Product Line scope defined, the next steps involve creating the organizational and guidance documentation and processes.

   a. **Product line adoption plan.** The adoption plan is the roadmap to take the organization from its current state through implementation of the Product Line. The plan may be as simple as a plan of action with milestones (POAM), or as elaborate as a multi-year transformation roadmap with extensive state models, action descriptions, reporting requirements, and assessment tools. The adoption plan should cover the full range of actions that are needed to implement the Product Line, call out the products that will be created at each step, and assign responsibility for accomplishing the work and delivering each product.

   b. **Organization chart and assigned personnel w/duties.** Adopting a Product Line approach includes adopting an organization structure suitable to operating the Product Line factory once it is established. The Product Line team includes business and technology managers and workers. Market analysts and marketers, software and requirements engineers, architects and test engineers, as well as business analysts, financial and business managers, configuration managers, and customer support personnel are all needed at some point to establish and operate the Product Line (Northrop, 2004). It is very important that managers recognize the difficulty in changing an

organization within the DoD and ensure that the assigned team is both capable and supported.

c. **Develop risk management process.** A formal structured approach to risk management is an essential tool for any complex undertaking. There are numerous models to choose from with the critical attributes being that the Product Line Manager is comfortable with the tool selected, and the tool is both usable and informative.

Phase II: Establish Core Assets

Phase II starts the execution of the Product Line adoption plan. The business case analysis, economic model, technology assessment, market assessment, and funding plan all remain living documents that need to be updated as the project evolves. The adoption plan, organization and manning document and risk management process become the operations template for day to day activities.

Once the decision has been made on what to build, work can begin on creating the core asset base. This section is written from the perspective of a reactive approach, where you start with an existing product as the first member of the Product Line and use that seed product to populate the initial core asset base. To operate as a factory, the Product Line needs established processes and procedures to use repetitively to create consistent results (Northrop & Clements, et al., 2007, Product Line Essential Activities section). Many of those procedures deal with creating the core asset base. Some deal with creating products from the core asset base, and the rest describe supporting the product in the field and growing the user community. Through the balance of this section, the processes that are part and parcel to the work and products at hand are critical parts of what must be created to establish the Product Line.

1. **Decompose assets from seed product.**

   a. **Define requirements, engineering process, and document initial product requirements.** There are many advantages and some challenges if you use an existing product as the starting point for a Product Line. Among the advantages of using existing assets includes having a working product that has been tested and possibly certified. Challenges include adapting existing processes, procedures, and organizational structures to a Product Line model. Also, the requirements engineering process for a Product Line differs from that of a standalone product in important ways. Requirements engineering includes the processes of elicitation (the process of listing and defining the requirements set), analysis, specification, verification, and management. These processes are used to define, refine, document, ensure correctness and completeness, and schedule and coordinate activities to formally state product requirements. When a Product Line is involved, elicitation must capture all the anticipated variation points across the lifetime of the Product Line (Northrop & Clements, et al., 2007, Requirements Engineering section), leading to a potentially larger community of stakeholders than for a single product. Since elicitation focuses on scope, there will be both a Product Line scope and a product scope that must be agreed upon. It is expected that the requirements engineering process will result in changes in the scope description. The requirements documentation

should be used for the existing product as the starting point for the Product Line requirements engineering process. Requirements analysis for a Product Line is focused on finding the commonalities and identifying the variations. These are the same commonalities and variations that should be found in the scope document. Again the requirements analysis will drive further clarification and definition into the Product Line scope. When the requirements specification is written, it will include both the Product Line-wide set of requirements and product-specific requirements. Both elements will require verification by the projected user communities. The requirements engineering process should be applied to both the core asset development and to product development.

b. **Capture architecture, define development and evaluation processes.** Start with the existing architecture from the existing product, and incorporate the changes and restructuring required to support a Product Line. Important differences revolve around the ability to establish and implement variation points in the products within the structure of the selected base architecture. Once established, the architecture must be fully documented and evaluated. Formalized and repeatable techniques and procedures have been developed by SEI (Northrop & Clements, et al., 2007, Architecture Evaluation section) and others that can be used with Product Line architectures.

2. **Capture and document test assets.** The existing product was produced and tested in a formal manner. The artifacts from that process form the starting point for the Product Line test assets. Test artifacts include the following:

   - test documents, including strategy, test plans, and test reports;
   - test cases;
   - test data sets;
   - test software, including harnesses or scripts; and
   - associated processes.

   For a Product Line, the test program must consider the variation points that occur throughout the development process and start testing the software artifacts as early as possible (Northrop & Clements, et al., 2007, Testing section).

   Because Product Lines reuse core assets with variations to produce products, the number of possible combinations of unique sets of assets can become very large as the number of products expands. The test program must be designed to start testing software artifacts as close to the variation points as possible to minimize the test permutations.

3. **Develop and document the process for developing or acquiring new components.** The core asset base (Northrop & Clements, et al., 2007, Core Asset Development section) includes the full suite of things used to create a product in a Product Line. Examples include architecture descriptions, requirements documents, code components, processes for developing or evaluating software, and tools. New assets are either developed or acquired to support new product requirements. Some are off-the-shelf (commercial or

government), some are developed (in-house or commissioned), and some are created by implementing new variation points in existing assets. Changes to the Product Line requirements and architectures supporting new behaviors or aspects will specify the components to satisfy the needs and how those components will integrate into the product. The process of acquiring new components should include a specific development process to incorporate the variation mechanisms specified in the architecture for the Product Line(Northrop & Clements, et al., 2007, Component Development section). New components may also be mined from existing assets in repositories like the Navy SHARE and NESI repositories, or from open source software. In each case, as a component is brought into the asset base, it must also include the full interface definition, any needed code to integrate the component into the architecture, and an appropriate variation mechanism. The interface definitions must be clearly documented, based on published open standards, and include all information required to support integration by a third party.

4. **Develop and document the Product Line configuration management process.** Starting with the configuration management plan for the existing product and its artifacts, develop an expanded plan for the Product Line. Within a Product Line, the core asset base and the family of products must all be managed together (Northrop & Clements, et al., 2007, Configuration Management section). Each of the assets requires configuration management so that all their component parts, interface descriptions, variation points, and other documentation are versioned and controlled. Similarly, the products are versioned and controlled. Since the assets are used on more than one product, changes to one asset needed by one product must be managed in common with all the other products that use the same asset. The configuration management tools must be complete and provide very sophisticated tracking of products and assets and their interrelationships.

Figure 5

Phase III: Develop Product Line Production Processes

The Product Line should be designed for ease of assembly and integration from the earliest architecture definition through development of the production plan. Using the initial existing product as a basis, the assembly and integration plans should inform the architecture development, core asset development, and the testing plan. This precept is a critical component of the Product Line production process.

1. **Develop and document the prescribed way assets will be assembled into a product.** The integration plan from the existing product may be suitable to use as a starting point and should be assessed. Product integration within a Product Line involves combining core assets from the core asset base and possibly adding unique assets. The variation mechanism employed within the architecture is used during integration to achieve the behaviors and aspects that discriminate the current product from other members of the Product Line. How that variation mechanism is to be used in assembling the product, and how the components are to be integrated, is dictated by the architecture and documented in the production process.

   The production tool set is driven by the architecture and the variation mechanism. Among the tools that may be leveraged for production, are interface languages like the Interface Definition Language (IDL) and Object Constraint Language (OCL) (Northrop & Clements, et al., 2007, Software System Integration section) that allow one to check the interfaces

automatically for consistency and completeness; the use of wrappers to incorporate components found through mining whose interfaces are not controlled within the Product Line; middleware that isolates the applications from the data generators and the user interfaces; and system generators that are actually computer programs written to select components and set their variability based on parameters provided to the generator at run time. Transitioning from a standalone product to a Product Line may force changes in the production tool set to accommodate implementing and managing variability.

2. **Develop and document product line support process.** Once a production plan is established, programs need to update the business case and economic model. The cost of operating the factory will be driven by the products being built and the staff needed to maintain the assets and build, test, and deliver the products. The organization chart and manning plan should be updated as required to incorporate production and revise the economic model to reflect the current understanding of projected costs.

An integral part of getting a Product Line established is the customer base (Northrop & Clements, et al., 2007, Customer Interface Management section). Products in the field must be supported and new products fielded to achieve the most benefit from the Product Line approach. In the initial market survey, sets of potential customers will be identified who are able and willing, but reluctant. Some of the Product Line support team's responsibilities include keeping current customers satisfied and growing the Product Line by finding new customers for existing or new products.

All of these activities require funding. The Product Line Manager must create a funding profile based on the organization, tasking for creating new assets and products, and tasking for maintaining and supporting existing products. The Product Line documentation should provide a solid basis for estimating funding requirements and determining funding requirements.

Figure 6

Phase IV: Develop, Document and Deliver New Product Variations

When the initial set of Product Line processes, assets, and plans are complete and the organization has been established and manning is in place, it is time to use the factory to create the second product in the Product Line. A legacy of the first product is that many of the analyses and initial process documents will have been created as "lite" versions, designed to document what is known at the time. These materials will serve as place holders for later elaboration as processes are tested and knowledge is gained. The testing, elaboration, and revisions to the Product Line documentation and operations are critical objectives during development of the second product in the line.

1. **Develop new product requirements.** The first step is to use the Product Line requirements development process and the existing Product Line requirements document to develop and document the requirements for the second product. At the same time, the additional product is added to the economic model, and the new product behaviors and aspects are reviewed against the Product Line scope to ensure they fall within the set of "in" characteristics. In the event the scope is revised, a review of the technology assessment and the business case should be undertaken to ensure the changes do not invalidate prior work.
2. **Review new product against the Product Line architecture.** The Product Line architecture must support the full set of product requirements. If the new product requires behaviors or features that cannot be supported by the architecture, either the architecture must be revised or the product will not fall within the scope of the Product Line. The new product may require an addition to the architecture to incorporate an additional variation mechanism

or a method to incorporate outside assets that were not originally contemplated by the architect. In any event, the requirements and the architecture must work together before moving forward. Any changes to the architecture must be fully documented and reviewed. An assessment report on the process must be created to capture the results and evaluate the effectiveness and validity of the architecture development and process when complete.

3. **Update core asset base and unique assets to support the new product.** New core assets, variation points in existing core assets, or unique or outside assets (Northrop & Clements, et al., 2007, Mining Existing Assets section) may be needed for the new product. Using the component development process already devised, update the assets to meet product needs. Evaluate these processes and procedures, update them as needed, and generate a report documenting the results.
4. **Assemble and integrate product assets.** Use the assembly and integration plan to create the new product. Production should use the production tools previously selected to demonstrate their suitability and sufficiency for completing the task. The results of this work will be a product ready for final testing along with a report on the efficacy of the process and the tools.
5. **Execute product test strategy.** The test strategy includes testing at every level of development and integration. While the testing for the original product may all have been conducted after coding and integration, the strategy should have been revised. For the Product Line, it is essential to test components as they are developed for the core asset base, incorporated from outside sources, or modified to incorporate new variation points and behaviors. For a new product, the test documents, test cases, test software, and test data may all require updates to reflect changes in the assets and changes in the requirements of the final product. The test program will start well before assembly and integration. Following test completion, a test process assessment report is needed to inform updates and adjustments to the test strategy for future products.
6. **Evolve and update Product Line growth and support team.** At initial product release, critical support functions must be in place. Configuration management (CM) and customer care are two of the most important. Configuration management for a Product Line was originally implemented in developing the processes and procedures for standing up the Product Line. Customers now become stakeholders and participants in the CM process. Product Line growth is fueled by finding new customers for existing products from among the able but reluctant potential customers, or by working with potential customers to develop new products within the line. The support team in a commercial environment would include a marketing group for this activity. The product growth group serves the same function in the DoD environment.

   Customer care includes supporting initial integration of the Product Line products into the customers systems or platforms; establishing a defect reporting, correction, and feedback system; and working with customers on their needs for product improvements or adding additional product features. This part of the support organization is essential to maintaining and growing a

Product Lines footprint. Everyone grudgingly accepts that software products will have defects, but no one happily tolerates non-responsive customer support or continues to buy products that cannot or will not address and correct the defects.

The support team is also responsible for the development of a cost/price model (an adjunct to the economic model) to incorporate the support costs into the development costs for products from the Product Line. Since the support team is shared across the Product Line, the incremental cost of supporting a new product should be less than that experienced by standalone products. Other aspects of the support costs include addressing software reliability and problem resolution. Based on past experience, the reuse of assets is expected to improve their reliability. Problem resolution times will depend on the effectiveness of the factory processes and the configuration management process. All of these costs should be collected and used to refine and update the cost/price model and improve its ability to project conditions as more and new products are added.

7. **Define a product release and distribution strategy.** During the initial technology assessment, care was taken to determine the best apparent set of practices, tools, and technologies to incorporate in the Product Line. If the Product Line is successfully established, there is a danger of becoming wedded to the successful past as time passes and technology moves ahead (Northrop & Clements, et al., 2007, Technology Forecasting section). It is critical to transform the technology assessment into a technology roadmap that provides for continuing assessment, evaluation, and migration as tools, techniques, and processing evolve. Sometimes the technology change will enable new behaviors and allow products to meet new or different performance requirements, while other advancements may enable reduction in the cost or time to field new products within the line. Each technology improvement offers an opportunity to grow the Product Line by meeting the performance, cost, and schedule requirements of new customers.

Another plan needed for the support team is the Product Line Growth plan. The growth plan incorporates deliberate strategies to find, inform, learn from, and collaborate with customers for current and new products. The growth plan is informed by the technology roadmap as well as the cost/price model and the Product Line scope. Potential approaches to Product Line growth within the DoD include use of federated repositories for Product Line and product descriptions, forming communities of interest in the Product Line domain, and enterprise wide workshops and symposia on Product Lines and better buying power.

Enabling Product Line Success

Product Lines require technical and business constructs which are also found in Open Architecture systems. Technical examples include reliance on core components, adherence to published interfaces, and use of common services to keep the implementation both loosely coupled and modular. The introduction of an open business model (OBM) is also important for Product Line success. An OBM is an approach for doing business in a transparent way that leverages collaborative innovations of numerous participants across an enterprise, permitting shared risk, maximized asset reuse, and reduced total ownership costs. Noted management scholar Henry Chesbrough (2006) has distinguished an open business model from a traditional business model as follows:

> A business model serves two important functions: 1. It creates value; and 2. It captures a portion of that value. It creates value by defining a series of activities from raw materials to final customer that will yield a new product or service with value being added throughout the various activities. The business model captures value by establishing a unique resource, asset, or position within that series of activities, where the firm enjoys a competitive advantage.

Alternatively, he describes an open business model as follows:

> An open business model uses this new division between innovation and labor—both in the creation of value and in a capture of a portion of that value. **Open models create value by leveraging many more ideas, due to their inclusion of a variety of external concepts.** Open models can also enable greater value capture, by using a key asset not only in the company's business, but also in other companies businesses (Chesbrough, 2006).

Incentivizing Product Lines

Programs that receive ample funding to conduct their own unique development of systems, sub-systems and components have little incentive to seek opportunities for reuse and participate in Product Lines. A 2006 survey conducted by the Navy's Open Architecture Enterprise Team (OAET) found that 74% of those interviewed indicated there were no incentives for employees to identify opportunities for reuse, 50% said there were no incentives for programs to reuse, and 68% said there were no incentives for programs to develop reusable assets (OEAT Survey, 2006).

The current structure for developing systems includes rules and processes which are often contrary to achieving Enterprise value and cost efficiency. It follows that in order to achieve change, careful crafting of incentives is important to gain desired results.

Provide Incentives for Creating and Using Product Lines

Reducing the program budget to a level that does not support building the available component from scratch can put enough pressure on the program to dictate use of the Product Line component. Half of the resulting savings could be held in reserve and, after component integration, released back to the Program Manager for feature additions or upgrades on any Product Line item the Program Manager believes appropriate.

Remove Incentives for Bad Behavior in Acquisition

Sole-source award programs where lack of competition drives prices higher and encourages vendor lock have become the norm for the Naval Enterprise. OA and Product Lines must become mainstream practices within the Enterprise to remove incentives for bad behavior in acquisition.

Expectations should be established that when a program expects to award contracts above a fixed level (for example, programs over $10 million for R&D alone), that the program can benefit from Open Architecture and Product Lines. The Naval Enterprise must require these programs to move to OA and Product Lines.

Sponsor Holds Contests for High-Performance Acquisition Behavior and Product Lines

How can the Enterprise know how good it can be without a challenge? Rewarding excellent or appropriate acquisition behavior with benefits that help the program can only cause more good behavior.

Support and Collaborate with Program Managers

Program Managers are being asked to take on a new business model. This will require learning and effort. They must own and adopt the new model so that Open Architecture and Product Lines can be successful. The Enterprise must resist the tendency to overburden Program Managers with rules and process, on the premise that PMs can be prevented from failing. We should, on the other hand, provide sufficient tools to give them a place to start with Product Lines and interactive support to provide collaboration in the adoption and development of the new business model. We must open up the armory, issue our most precise acquisition weapons, and pilot our way to success by allowing failures and successes to give professionals experience in the competitive marketplace. We should pare back management oversight to essential measurements, and stress planning and iteration, rather than rigid adherence to process and rules. Programs are completed by hard working people making good decisions.

Shift Responsibility to Resource Sponsors

Functional requirements and money flow down from the Resource Sponsors. These important individuals are customers that must engage the Program Managers, encouraging them to invest in Product Lines. Product Lines can be a solid investment for the Resource Manager, since owning a reusable and transportable feature that can be integrated and deployed quickly on new and/or existing platforms *saves money, time, and improves operational availability by reducing resource requirements for longer test cycles*.

Restrain Resources to All Programs

According to a study performed by Lt. Col. Dan Ward (2009), USAF, programs over $10 million in value have a 0% chance of successfully delivering a working product that meets its performance requirements on schedule. By allowing deadline slip and delaying delivery, the probability of project success worsens. Comparatively, smaller, less complex programs that leverage Product Lines are more likely to be delivered on time and on budget, with a direct correlation between smaller budget and shorter execution times for program success. Reducing and restraining a program from the inception can result in savings that result from dramatic restructuring and rethinking of the acquisition program.

Figure 7

Create a Marketplace for Competition and Small Business

As acquisition professionals, we are responsible for the outcomes of our development programs. The path to successful OA Product Line programs begins with the Request for Information (RFI), when the outline of rules and how the program will be competed is defined to the marketplace. The target system should be decomposed into unit sizes that are functionally decoupled from the platform, yet cohesive in nature. A useful example is the SONAR systems installed on ships or submarines. Although the platform is different, much of the implementation can be shared between the two. Defining roles for competition, such as having a designated Prime Integrator and designated Application Subsystems Developers (primarily drawn from small businesses) can reduce the conflicts between large and small business. In this case, we could limit the Prime contractor to only performing integration, because of the conflict of interest that may arise if that provider were allowed to develop and select applications. By their position, Primes would have an advantage over the subsystem developers.

Within the Product Line construct, the core asset base provides a natural place to compete components. The ability to use assets created within or outside of the Product Line factory organization, including COTS and mined assets, allows the Product Line manager to establish and maintain an open competitive environment based on value and a natural entry point for small business.

Provide Web-Enabled Tools to Encourage Transparency

In many cases, programs lack the internal communications capabilities they need to effectively work across traditional stovepiped programmatic/domain/Service boundaries. For each program, a common, easy to use web-based collaboration portal where project

information is securely held, and made available to the community as appropriate, is required. This environment would provide a green field for web enabled program management, including capturing products associated with ongoing development and deliveries, and providing transparency to all stakeholders. Some larger programs have filled the void with collaboration tools for their internal use, demonstrating the viability of this mechanism. The Naval Enterprise may in the future provide a standard environment for use in any program that needs such a resource.

Apply Governance to Protect Small Business

Small Business Innovative Research (SBIR) contracts are used by highly innovative and competitive small businesses to cleave a foothold into the defense marketplace. Without governance, large firms have shown a repeated pattern of cutting small businesses out of the marketplace. When this occurs, the government loses a competent innovator and price competitor—increasing the potential for mediocre performance, cost overruns, and schedule delays.

Conclusion

The Naval Enterprise is at a sea change with respect to its acquisition behavior. More highly advanced systems must be acquired with fewer resources. During a panel discussion at the January 2011 Surface Navy Association Symposium, RADM Dave Lewis, USN, PEO SHIPS, discussed cost growth in ship acquisition over recent years. Projecting that growth into the future, he posited that either the Navy would not be able to afford ships, or the Navy/Industry team must innovate and find ways to acquire our ships at lower prices while maintaining a profitable industry. With a large fraction of the cost of a surface combatant dedicated to the combat system, and a significant portion of the ship's systems cost dedicated to software, Product Lines and Open Architecture offer a real opportunity to innovate and save precious taxpayer resources. Open Architecture is a proven method within the Naval Enterprise to reduce total ownership cost. Product Lines have enjoyed popularity within leading corporations for years, and are a good fit for encouraging savings within the Naval Enterprise. Together, Open Architecture and Product Lines provide the best opportunity to save money and improve performance in Naval Enterprise Acquisition.

References

Chesbrough, H. (2006). *Open business models.* Cambridge, MA: Harvard University Press.

Clements, P., & Bergey, J. (2005, September). *The U.S. Army's Common Avionics Architecture System (CAAS) product line: A case study*. Pittsburgh, PA: Carnegie Mellon University, Software Engineering Institute.

Clements, McGregor, & Cohen. (2005, February). Technical Report CMU/SEI-2005-TR-003 ESC-TR-2005-003.

Dally, B. (2010, April 29). Life after Moore's Law. *Forbes.* Retrieved from http://www.forbes.com/2010/04/29/moores-law-computing-processing-opinions-contributors-bill-dally.html

Defense Acquisition University. (n.d.). Terms & definitions. Retrieved from https://acc.dau.mil/CommunityBrowser.aspx?id=22108

DoD. (2009, April). *Creating a DoD strategic acquisition platform* (Report of the Defense Science Board). Retrieved from http://www.acq.osd.mil/dsb/reports/ADA499566.pdf

DoD OA Working Group. (2011, March 28). *Better buying power: Understanding and leveraging data rights in DoD acquisitions.* Retrieved from https://acc.dau.mil/CommunityBrowser.aspx?id=436677&lang=en-US

GAO. (2009, March 30). *Defense acquisitions: Assessments of selected weapon programs* (GAO-09-326SP). Washington, DC: Author.

Guertin, N. H., & Clements, P. (2010, April). *Comparing acquisition strategies open architecture vs. product lines*. Monterey, CA: Naval Postgraduate School.

Kang, K. C., Sugumaran, V., & Park, S. (2009, December 22). *Applied software product line engineering.* Boston, MA: Auerbach Publications.

Northrop, L. (2004, September). *Software product line adoption roadmap* (Technical report CMU/SEI-2004-TR-022). Retrieved from http://www.sei.cmu.edu/library/abstracts/reports/04tr022.cfm

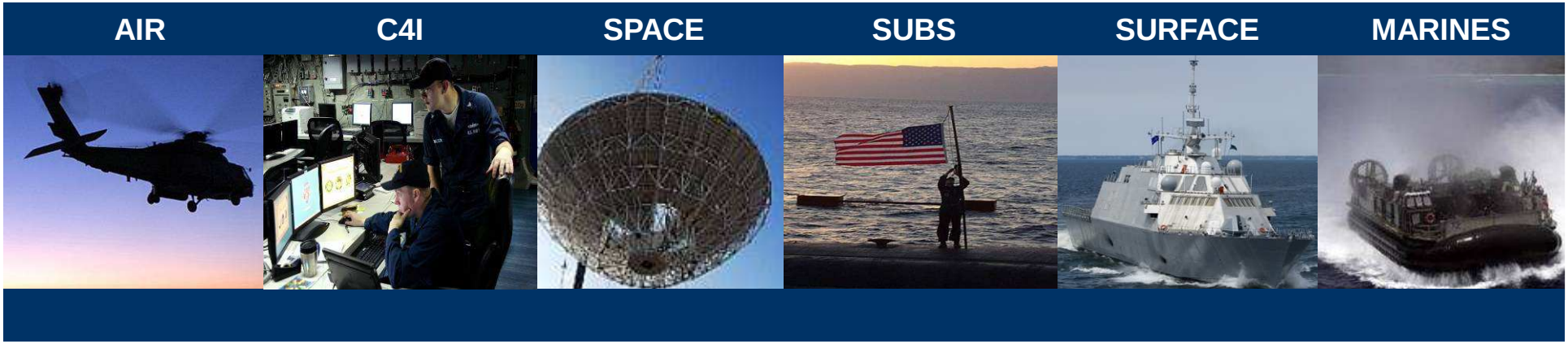
Northrop, L., & Clements, et al. (2007, July). *A framework for product line practice, version 5.0.* Retrieved from Carnegie Mellon University, Software Engineering Institute (CMU SEI) website: http://www.sei.cmu.edu/productlines/frame_report/index.html

Open Architecture Enterprise Team (OAET) Survey. (2006).

Software Engineering Institute (SEI). (n.d.). Software product lines. Retrieved from http://www.sei.cmu.edu/productlines/start/index.cfm

Ward, D. (2009, November–December). There are no facts about the future. *Defense AT&L*.

Open Architecture Product Lines



11 May 2011

Mr. Brian Womble
Assistant Program Manager
For Open Architecture and Systems Engineering
PEO IWS 7.B

Important Concepts

- Competition and Innovation

- Rapidly Fielding and Upgrading Systems

- Software and Hardware Design Reuse

Product Lines (introduction)

- A set of components or products created from shared core assets delivering features and capabilities that address the specific needs of a specific market segment or mission capability.
  - Smart Phones
  - Smart Phone Software
  - Automobiles
  - Personal Computers
  - Marine Radars
  - Marine Navigation Systems





- Core Assets include drawings, architecture, patterns, code modules, test suites and tools, and any other cumulative product from the engineering effort

Open Architecture (introduction)

- Modular designs with loose coupling and high cohesion
- Continuous design disclosure
- High Reuse of designs of components and systems to minimize cost
- Enhanced transparency
- Competition and collaboration leading to development of alternative solutions and sources
- Investment based on analysis of which components will change most often based on technology

Competition through open access to qualified third party providers for components

Open Architecture Product Lines (introduction)

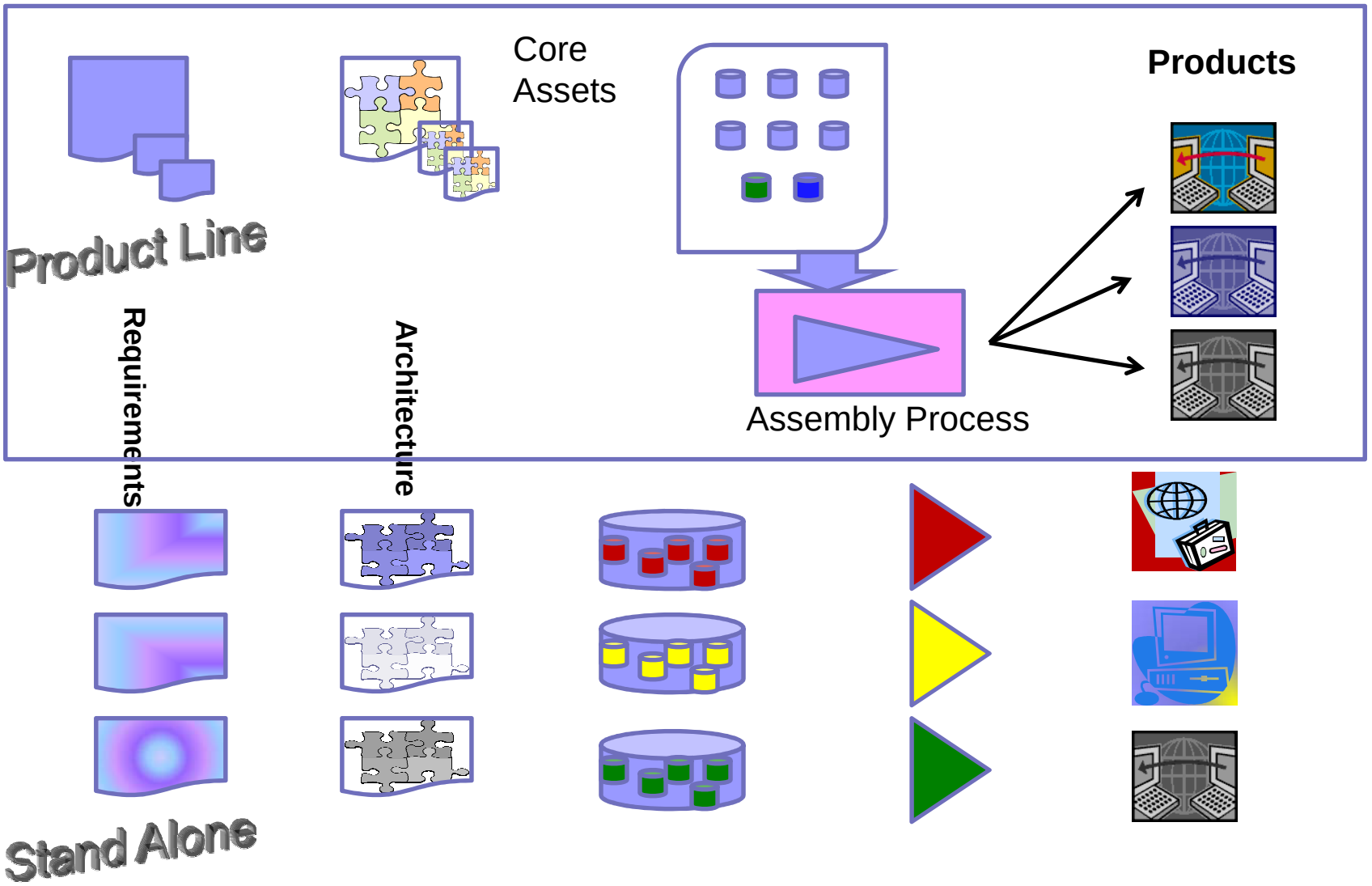
- Open Architecture Core Assets
  - Open managed reused components – strategic reuse
  - Published architecture that specifies how features and behaviors are varied between products
  - Assets can be competed as technology advances and/or mission needs change
  - Reusable test scripts, plans, assets and harnesses shorten process and simplify execution

Combining the power of OA with the leverage of Product Lines

Product Line Advantages in the DoD Marketplace (Benefits)

- Strategic Reuse
  - Lowers Cost
  - Lowers Risk
  - Shortens Development Time
- Product Line Maintenance
  - Shared Core Assets - maintained for one is maintained for all
  - Common Code between products yields fewer software faults as number of products increases
  - Built in variation mechanisms simplify product evolution – changes or additions to requirements generate a new product based on core assets plus some new or altered module(s)

Product Line Advantages in the DoD Marketplace



Relative Costs, Standalone Versus Product Line (Benefits)

- Standalone
  - Productivity – A
  - Schedule – B
  - Cycle Time - C
  - Quality – D
- Product Line
  - Productivity – 3 to 7 Times A
  - Schedule – 1/50th to ½ of B
  - Cycle Time – 1/3 to 1/5 of C
  - Quality – 7 to 10 times better than D

Initial Product in Product Line; Costs may be equal or higher
Costs for Additional Products Decline as more are Added

SEI Case Studies: http://www.sei.cmu.edu/productlines/casestudies/

Some Opening Arguments (Starting up a Product Line)

- Data Rights
- Programs interested in Sharing Risk
- Some shared Requirements
- Organizational and Funding Construct for Shared Production
- Government to Government Producer/Customer governance structure
- Need for multiple similar products suitable for a product line

Starting or Transitioning to a Product Line (Startup)

- Pilot Projects
- Use Existing Products and Artifacts as Entering Arguments for Core Assets, Processes and Tools – Re-engineering to Adopt the Product Line Paradigm
- Establishing a Framework for the Naval Enterprise and Using that Framework as a Guide to Achieve Consistent Implementation Concepts and Approaches
- Learning and Adapting

Product Line Startup Phases

- Phase I – Deciding What to Build: Analysis, Scoping, Funding Plan, Product Line Adoption Plan, Risk Management, and Initial Organization Chart
- Phase II – Establishing Core Assets: Requirements, Architecture, Software Modules, Test Assets, Middleware, Test Plan, and Configuration Management Plan
- Phase III – Develop the Product Line Production Processes: Assembly Plan, Production Tools, and the Product Support Plan
- Phase IV – Use the Product Line Variation Mechanism to Develop, Deliver, and Support Additional Products

Phase I: Deciding What to Build

- Does your product fit in a Product Line?
  - Similar related products envisioned?
  - How do they vary? What mechanism implements the variation?
- Is there a market for the Product Line?
  - How wide? How Deep?
  - Are there willing and able customers?
- Is the technology available to implement the product and variation mechanism
  - Suitable technology?
  - Sufficient technology?
- Does the approach make economic sense?
  - Economic Model and Business Case
  - Are there over-riding intrinsic value benefits?
  - Are funds available for implementation/transition?

Phase II: Establish Core Assets

- Requirements Engineering Process and Initial Product Requirements
  - Variation points across the envisioned Product Line
  - Product wide and product specific requirements
- Architecture and Architecture Analysis
  - Define the variation mechanism
  - Capture the variation points
- Capture and Document Test Assets
  - Test Documents
  - Test Cases
  - Data Sets
  - Harnesses and Scripts

Phase II: Core Assets (Continued)

- Components – Supporting the Behaviors and Aspects as Specified in the Requirements in the Manner Prescribed in the Architecture
  - From existing product
  - New development
  - Acquire from others
  - All built or configured to implement product variation as specified in the architecture
- Configuration Management Process
  - All the assets
  - All the products
  - Tools capable of managing the “many-to-many” relationships between core assets and products

Phase III: Develop the Product Line Production Process

- Develop the Product Line Assembly Plan
  - Informed by the architecture and components from the core assets
  - Implements the variation mechanism(s) planned at architecture development
  - Based on initial product artifacts when using a reactive implementation
- Develop and Document a Product Line Support Process
  - Product distribution and integration support
  - Customer feedback and issue management
  - Product defect correction management
  - Product improvement planning and implementation

Phase IV: Filling the Product Line

- Create the 2nd Product
  - Use the Product Line factory and the variation mechanism to create the 2nd Product
  - Update the plans, processes and analyses as lessons are learned
  - Add to the core asset base as needed to create the new products
- Add Scope to the Product Line
  - Initial envisioned products will never be exactly what gets produced
  - Unforeseen customer needs will require products that extend the scope of the Product Line or change its variation points

Enabling Product Line Success (Startup)

- Establish Open Business Models
- Use Incentives
- Support and Collaborate with Program Managers
- Engage Resource Sponsors as Participants
- Implement Web Enabled Tools for Transparency
- Apply Governance to Protect Small Business

Summary (Why Bother)

- Current federal budget deficits are unsustainable and while all sectors will be carefully scrutinized and trimmed, trimming defense dollars is less personal than trimming Social Security and medical benefits or slicing away education support funding from people we know.
- While fewer dollars are available for defense systems, the cost growth of those systems continues to outpace similar technical advances in the commercial sector.
- Open Architecture Product Lines aren't always the solution, however, when they are a solution they present an opportunity to reduce the cost of software intensive systems while improving capability, quality, and reliability and giving industry an opportunity to continue to be profitable.